Requirements for the BTeV Muon System

The BTeV Muon Group

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1 Introduction

This document describes the requirements the BTeV Muon System. This document will be updated as the project develops and we better understand the production process.

2 Requirements for the BTeV Muon System

The considerations that have gone into determining the requirements for the muon system include:

- The physics goals of the experiment
- The characteristics of both the events of interest and background events
- The physical size of the C0 hall and other detector components
- The robustness of the detector technologies
- Environmental, Safety, and Health (ES&H) issues

2.1 Physics requirements

These requirements are determined by the physics goals of BTeV.

1. **Luminosity**: The muon system must be able to operate at a bunch crossing time of 396 ns with a maximum luminosity of $4 \times 10^{32}(\mathrm{cm}^2\mathrm{s})^{-1}$.
2. **Lifetime**: The muon system must operate consistent with its design goals over the maximum lifetime of the experiment (10 years).
3. **Momentum resolution**: The "stand alone" momentum resolution of the muon system must be better than $\sigma_p / p = \sqrt{(0.25)^2 + (0.01p)^2}$.

2.2 Toroid requirements

1. **Bending power**: There should be two toroids in the (single) muon arm, each with a minimum field of 1.4 T and minimum thickness of 0.8 m.
2. **Magnetic field map**: The magnetic field must be known everywhere in the toroids to 1%.
3. **Magnetic field uniformity**: The magnetic field in each toroid must be uniform to 15%.

2.3 Proportional tube performance requirements

1. **Timing resolution**: The collection time for all proportional tube hits should be less than the beam crossing rate.
2. **Occupancy**: The maximum rate in any single proportional tube should be less than 200 kHz.
3. **Efficiency**: The typical efficiency (when measure in coincidence with other tubes sharing the same fiducial volume) of each proportional tube should be 98% of greater. (Edge effects are minimized in this definition of efficiency.)
4. **Efficiency over lifetime**: The muon system efficiency over the lifetime of the experiment must be consistent with the BTeV physics goals. Currently it is thought that any aging effects will be negligible.
5. **Spatial resolution**: The position resolution of the proportional tube planks must be 2mm or less.

2.4 Detector installation and support requirements

1. **Position reproducibility**: The position of the octants should be reproducible to 0.25 mm in *x*, *y* and *z* after they are moved (*e.g*. for maintenance.)
2. **Removal/exchange**: the muon octant plates should be readily removable for maintenance. It must be possible to remove an octant during two 8 hour shifts, and replace an octant in two 8 hour shifts.
3. **Internal survey**: The coordinates of the individual muon proportional tubes within each octant needs to be known a priori to a level such that it does not contribute to the expected resolutions (2 mm) of the muon proportional tubes.
4. **External survey**: The coordinates of the station fiducials with respect to the BTeV absolute coordinate system needs be known a priori and maintained over the lifetime of the experiment. Final alignment transverse to the beamline and station position monitoring will be performed via software. The location of each station along the beamline (*z*) with respect to the experiment center must be determined within 2.3 mm over the face of the detector. The station to station alignment, in terms of rotations about the beam axis, must be matched to within a milliradian (about a 2 mm shift around the rim of the detector). The station to station alignment, in terms of shifts transverse to the beam axis, must be matched within 2 mm
5. **Flatness**: The center of a circular slice of a tube must not deviate by more than a perpendicular distance of 0.5 mm from the ideal long axis of symmetry. This is a requirement for wire stability at high voltage.
6. **Roundness**: The tube inner radius must not deviate by more than 0.5 mm towards the center of the tube from the ideal radius of the tube. This is a requirement for wire stability at high voltage.

2.5 Geometry requirements

These requirements are constrained by the size of the experimental ball.

1. **Station depth in z**: each full detector station should not take more than 40.5 cm of space in *z* (the beam direction.)
2. **Acceptance**: Each full detector station should cover radii between 38 cm and 240 cm.

2.6 Correction dipole requirements

1. **Installation interference**: The correction dipoles and their associated cabling should not restrict or interfere with the installation of the muon detector stations and their supporting infrastructure.
2. **Radial size:** The muon system needs to provide coverage down to 38 cm (Geometry requirement 2). The correction dipoles and their associated cabling should not restrict or interfere with this coverage.

2.7 Control and monitoring

1. **Environmental monitoring**: The muon system needs environmental monitoring (pressure and temperature). In order to be sensitive to 1/10th of the plateau region in the smallest plank (the best case), the monitoring must resolve a change equivalent to a change in HV of 10V or a change in gas gain of 1×10^4 (nominal gain is expected to be 1×10^5). This corresponds to 1/200th of an atmosphere and 1 degree C.
2. **Gas mixture monitoring**: We need to monitor the gas mixture for changes in mixture condition equal to 0.1% (*e.g.* a change of a mixture of 85/15 Ar/CO^2 to 85.1/14.9).
3. **HV monitoring**: The muon system needs monitoring of the high voltage power supply voltage with a resolution of 2-3 V and current with a resolution of 0.1 μA.
4. **Gas gain monitoring**: The muon system requires monitoring of the gas gain and particularly needs to be alert to aging issues. The gas gain monitor must have a resolution equal to roughly 0.1% of the range of the plateau region, or repeated samples of the gain over the course of a 24 hour period must produce a measurement of the derivative in the gas gain with a resolution of about 3×10^{-5}/(day), roughly 1×10^4/(life of the experiment).
5. **Gas containment monitoring**: The gas mixture must be monitored for contaminants with a gas mass spectrograph.

2.8 Software Requirements

The software for the muon system refers to algorithms for track finding, monitoring systems, and diagnostic tools.

1. **Software standards**: Software development will conform to the *BTeV Software Standards* (under development).
2. **Muon Identification**: Muon identification software must be written which will perform track matching from the upstream spectrometer (a combination of pixel and straw tracks) to either hits or track segments in the muon system. The matching will be performed using the expected errors from the upstream spectrometer and the muon system and a confidence level will be assessed for the agreement. Where possible, an independent measurement of muon momentum will be calculated.
3. **Muon Calibration**: Software must be written to determine the geometry of the muon system and the efficiency of individual counters. These measurements will be estimated from data and included into the muon identification software at periodic intervals concurrent with significant changes in geometry or efficiency
4. **Front End**: The programmable components in the front end electronics must have software capable of setting and verifying thresholds, pulsing sets of channels, sparsifying and gating the signals coming from the tubes, identifying the board electronically, and communicating with the slow control system. Additional functionality will be included to fully exploit the capabilities of the hardware (*e.g.* the ability to shut off a channel if we fully develop channel fusing).
5. **Monitoring**: Software must be developed to monitor changes in muon system performance using the data and to monitor changes in the physical environment of the detector (*e.g.* temperature, high voltage, current to the plank, pressure to an octant, gas flow to an octant, status of valves in the gas system, gas gain, gas impurities, gas mixing percentage, etc.). This software will have limits where operators will receive an alert if parameters exceed limits. Implicit in this requirement is an interface to BTeV DAQ for slow controls.

2.9 ES&H requirements

The muon system will have subsystems (electrical and gas handling), which could constitute safety hazards. The electrical will have sub-systems that have low voltage and high current, as well as high voltage and low current.

1. **Electrical safety**: All electrical aspects of the muon system will conform to the Fermilab ES&H manual on electrical safety.
2. **Gas handling safety**: All aspects of the gas handling system will conform to the Fermilab ES&H manual on gas systems.

2.10 Electrical requirements

1. **Compliance with BTeV Electronics Standards**: The muon system will comply with *BTeV Digital Electronic Standards* (under development) and the Fermilab ES&H manual on electrical safety.

2.11 Front-end electronics requirements

1. **Noise on FE**: The digital section of the front-end cards must not impact the performance of the analog portion, consistent with the physics goals of BTeV. The low and high voltage delivery must not impact the performance, consistent with the physics goals of BTeV.
2. **Thresholds**: Thresholds must extend from no higher than 0.1 fC to 16 fC with a resolution of 0.03 fC.
3. **Channel granularity**: The maximum number of channels to be controlled by a single threshold is 8.
4. **Channel control**: A common high voltage is to be sent to each plank. Channels can be masked (shut off) digitally.
5. **Firmware**: The firmware for the FPGA on the front-end board must be downloadable in situ. Among other things, this allows us to add features if needed.
6. **Fusing**: Fusing of low voltage will be done with fuses that self-recover.

2.12 Internal Interlocks

1. **HV over-current**: Individual high voltage channels must have a programmable over-current trip.
2. **HV interlock**: The high voltage system must have an interlock that prevents delivery of high voltage in the event of a need to shut off the system quickly.
3. **Gas interlock**: The gas system must have an interlock that prevents delivery of gas, or shunts the main delivery to either a known pure gas source or nitrogen, in the event of a need to shut off the main gas system quickly.
4. **LV interlock**: The low voltage system must have an interlock that prevents delivery of low voltage voltage in the event of a need to shut off the system quickly.